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CYCLES IN SUNSPOT NUMBERS

by Gerould T. Lane

THERE have been many articles written about periodicities that are present in the main cycle of sunspots. This main cycle varies in length from about seven and one-half years to sixteen and three-quarter years, and during the past two hundred years has averaged about eleven years in length.

This variation in length of the sunspot cycle has been the subject of many theories and possible explanations, most of which depend upon some type of action and positions of the planets, and evidence has been offered by means of periodic tables to show that there are cycle lengths that correspond with certain planetary motions and positions.

While the periodic tables offered in evidence showed rather smooth sinusoidal curves, one has only to try periodic tables of different lengths to find that a rather smooth curve can be obtained with any length of periodic table that has enough lines, so that cycles or random figures of other lengths are depressed to a considerable degree.

This means that, if there are any true cycles in sunspot numbers, and if we are to attempt to determine their lengths by means of periodic tables, it will be necessary to make tables of every possible length and then compare or chart the amplitudes or strengths shown by all the tables. Such a chart is known as a periodogram.

The first study of sunspot numbers by means of a periodogram was made by Sir Arthur Shuster about the turn of the century. Many studies have been made since, but as far as I know, they were mostly made from the yearly figures, and hence could not have short enough steps to make possible accurate determinations of indicated cycle lengths.

The preparation of periodic tables requires great care in selection of the starting and ending points so that the tables will not have open ends, but will, on repetition, appear as continuous waves. In most time series, it is necessary to remove trend lines before good periodic tables can be made. This often involves making certain assumptions that could very possibly have a considerable effect on the results.

Sunspot numbers have approached quite close to zero eighteen times during the last two hundred years, and so by selecting starting and ending points in these low areas, the problem of a trend line can be ignored, and any long cycles will show only as changes in amplitude of the eleven-year average cycle, and be evident in an eleven-year moving average of the yearly numbers.

In order to give very accurate lengths to the indicated cycles, tables varying in length less than two one-hundredths of a year were prepared in all cases where a peak in strength was shown. Two hundred and twenty-six periodic tables were prepared for cycle lengths between three and thirteen years, and thirty-nine more prepared from the eleven-year moving average, from twelve to ninety-two years in length.

For this work the quarter-year values. (Jan. 1, Apr. 1, July 1, Oct. 1), were taken from the "Twelve-Month Running Average Relative Sunspot Numbers" as published by the Interservice Radio Propagation Laboratory, National Bureau of Standards, Washington, D. C., as IRPL-R23 issued Oct. 1945, "Solar-Cycle Data for Correlation with Radio Propagation Phenomena". From 1945 to 1953, the values were calculated using Zurich Provisional Relative Sunspot Numbers as published in the monthly supplements. All figures were adjusted to the nearest whole number.

These quarter-year values are shown in Table 1 and have been plotted on Chart 1 from July 1749 to October 1952. Generally, however, the values used in the periodic tables covered about one hundred and ninety-one years, or from 1754 to 1945. This was necessary in order to have the tables start and end as near to zero as possible. In some cases, it was necessary to expand or shrink this period to cover various wave lengths, but where this was required, it was still possible to start and end the tables at approximately the same values, even though considerably above zero.

In preparation of the periodogram, the high point, or what might be called the strength of each wave length, was recorded. Each table was designed to keep the high point in the center so the low points were at the ends of the lines where there is not a complete column in most cases. Generally, the difference between the high and low points is shown and called the amplitude of the cycle or wave.

Table 2 shows the relative strengths of the two hundred and twenty-six periodic tables between three and thirteen years in length. Chart 2 shows these strengths in graphic form. The table also shows the number of lines in each periodic table. The gaps on the graph are where changes in the number of lines in the table have been made as required by the changes in lengths of the lines, as every effort was made to use data for about the same interval of time.

It is easily seen from the chart that there are pronounced peaks in the graph for the following wave lengths expressed in years: 5.63 - 7.60 - 8.36 - 8.76 - 9.30 - 9.93 - 10.60 - and 11.25, the latter values being much greater than the others, and the 9.93 year wave being second in importance. Values below three years in length were studied but if there are any cycles of importance, they are suppressed by the twelve-month running average and the use of quarter-year values.

Table 3 shows the periodic table for 11.25 years. Each line contains the values for forty-five quarter years. Chart 3 shows this periodic table in graph form, and in addition gives the dates for the next high and low of this cycle based on the averages of the previous seventeen cycles.

Table 4 and Chart 4 show the periodic table for a wave length of 9.93 years. This is the second largest cycle and on the chart, the next low and high are shown. Table 4 is also a good example of the method used to tabulate wave lengths that are not whole numbers of quarter years. The last column has but fourteen of the nineteen lines, so the wave length expressed is fourteen-nineteenths of one-quarter year longer than 9.75 years or 9.93 years.

Charts 5 to 9, inclusive, show the graphs for the other wave lengths of importance and the dates for the next cycle for each wave length. No chart was made for the wave length of 5.63 years. This wave is apparently the second harmonic of 11.25 years and is of minor importance.

Study of these seven wave lengths of greater strength in my opinion seemed to show some overall relationship such as harmonics of some long cycle. I have shown in the calculation below that the wave lengths are very close to the 15th, 16th, 17th, 18th, 19th, 20th, and 22nd harmonics of 168 years. There is no evidence of the 21st harmonic.

11.250 multiplied by 15 equals 168.75
10.597 multiplied by 16 equals 169.55
9.934 multiplied by 17 equals 168.89
9.300 multiplied by 18 equals 167.40
8.762 multiplied by 19 equals 166.48
8.359 multiplied by 20 equals 167.18
7.600 multiplied by 22 equals 167.20
Average - 167.92 years

The question remains whether this apparent harmonic relationship was forced by randoms about 168 years apart, or whether the unusual strength at the 168 year intervals was in fact the result of the cycles. Further work is necessary to clarify this point.

This harmonic relationship of the waves found showed the need of a periodogram covering longer wave lengths. To make such tables having any value, it was necessary to depress these strong shorter cycles already found and especially the very strong cycle, 11.25 years in length. This was done by making an eleven-year running average of the January 1 values of the numbers shown in Table 1. This running average is shown on Chart 10.

The values of the eleven-year moving average were used to prepare thirty-nine periodic tables, between eleven and ninety-two years in length. The larger the wave length, the more crude was the table as there were fewer lines to each table, and it was more difficult to start and end the tables at the same values.

The strengths shown in each of the thirty-nine tables are plotted on Chart 11 and constitute a periodogram of the wave lengths covered by the tables. The shorter wave lengths are depressed to a much greater degree by the eleven-year running average. On a very crude form, we again find harmonics of some value that could be 168 years, as below.

84 multiplied by 2 equals 168
42 multiplied by 4 equals 168
26 multiplied by 6 equals 156
20 multiplied by 8 equals 160
16 multiplied by 10 equals 160
13 multiplied by 12 equals 156
12 multiplied by 14 equals 168

In addition to the above possible harmonics of 168 years, we can also see a 60-year, a 30-year, and possibly a 52-year cycle.

This periodogram and also Chart 10 show that the second harmonic of 168 years or a cycle 84 years in length is probably of great importance. Periodic tables of this length contained but two lines so it seemed wise to try to verify this length of eighty-four years by means of a running average of the eleven-year running average. A forty-two year average was selected as about the shortest that would give a smooth result.

Chart 12 shows this forty-two year running average plotted along with the eleven-year moving average as shown on Chart 10. Again, we are limited in our evidence by the loss of values at each end of the time series, but we do find a low point in 1814 and another in 1898 or exactly eighty-four years later.

For the benefit of those who believe that there is a planetary cause of sunspots, we should now look for correlations with motions and positions of the planets. At first glance, the 11.25 year cycle is much too short for the quarter-synodic period of Saturn and Uranus which is 11.34. However, these two planets vary a great deal in their angular velocities according to their distances from the sun. Their quarter synodic periods vary from 9.3 years to 13.5 years and, for the time under study, the periods averaged just over 11.25 years.

This is an interesting correlation, but requires further study and proof before it can be accepted that the major cycle in sunspots is caused by the motions and positions of these two planets. If Saturn and Uranus do cause this cycle, a greater strength should be shown by a table that is prepared using, as a starting point for each line, some position in the quarter synodic period of the planets rather than lines of rigid length. If less strength is shown, we would be justified in saying that there is no relationship between the major sunspot cycle and the quarter synodic period of Saturn and Uranus.

This turned out to be a major task, as the heliocentric longitudes for Saturn and Uranus have been published for but a part of the period covered by this study. Calculations for the years not published were made from "The Heliocentric Equatorial Coordinates of the Five Outer Planets" as published by the U. S. Naval Observatory.

Various tables were made, starting the lines at different positions of the two planets, and it was found that, when Saturn was thirty-five heliocentric degrees past its quarter synodic period with Uranus, the greatest strength was obtained. I call these "Epoch Tables" to distinguish them from the fixed length periodic tables.

While each line was started at thirty-five degrees, the maximum in the table came sixteen quarter years, or four years later, and was an average of eighty-three sunspot numbers compared to seventy-eight for a rigid periodic table of 11.25 years. The values of the two tables are plotted on Chart 13 which shows, for the Epoch Table, not only a greater strength or maximum value, but also a lower minimum, giving an overall amplitude of nine sunspot numbers more than the rigid table.

This is a very startling result and is very difficult to explain in any way other than by the actions of the planets. No other arrangement of sunspots in lines equals the strength of the quarter synodic period of Saturn and Uranus. As has been shown, the maximum values of rigid lengths of lines were considerably less.

The next cycle of importance in the periodogram has a length of 9.93. This is exactly the theoretical and also the actual length of the half-synodic period of Jupiter and Saturn. It seems to be a secondary cycle, as it shows strength only when Saturn and Uranus are in certain ranges of positions.

One might ask why Saturn and Uranus show strength of sunspots each quarter synodic period rather than each one-half synodic period as do Jupiter and Saturn, This could be explained by considering the major sunspot cycle as 22.50 years, as alternate cycles of the 11.25 cycle are positive and negative. In other words, in each one-half synodic period of Saturn and Uranus, there is a positive sunspot cycle, which is followed by a negative one. The positive cycle may act to cause high pressure areas on the surface of the sun. Gases moving from a high pressure area are anticyclonic and move in a clockwise direction. If the gases consist of charged particles, this will cause a positive magnetic effect or a south pole attraction.

The negative cycle may produce low pressure areas on the sun. Gases moving to a low pressure area are cyclonic and move in a counterclockwise direction. With charged particles, this will produce a north pole seeking or negative magnetic charge.

A great deal more study must be carried on, not only to verify these findings but to explain why no other planetary motions are shown in the main sunspot cycle. The other cycle shown in the periodogram have no planetary correlations that I can find. They may be harmonics of the 168 year cycle caused by 17 cycles of 11.25 years and 19 cycles of 9.93 years.

Perhaps planets, in order to cause sunspots, must have slow enough relative motions to be in active positions for a considerable period of time. Planets nearer the sun move much more rapidly and are in certain positions with other planets for a very short time. This might explain why Nelson at R.C.A. finds solar flares only under such conditions.

Another possible reason why Jupiter, Saturn, and Uranus could be the major factors in the cause of sunspots is that they are very oblate, having very large equatorial bulges, and that the equators of Saturn and Uranus are many degrees out of line with the planes of their equators. They are also revolving very rapidly. Their bulges are acted upon by the sun and the bulge of the sun is acted upon by the planets. This is what is known as a couple and the resulting forces are said to be much greater than the tidal effect.

The earth has a bulge that is shown by the 27-mile difference in diameter at the equator compared with the polar measurement. The attraction of the sun on this small bulge causes the precession of the eqinoxes, which is the clockwise motion of the poles over a period of twenty-six thousand years.

Jupiter, Saturn and probably Uranus have bulges of many thousands of miles, which must have very strong action on the gases at the bulge of the sun. The attraction cannot be calculated as the densities of the equatorial bulges of the planets are not known.

If these forces are of sufficient strength, combined forces of the planets in certain relative positions could cause high pressure areas approaching the equator of the sun on the average of every 22.68 years and then, on the average, low pressure areas 11.34 years later. The gases of the sun leaving the high pressure areas would move clockwise and cause positive magnetic charges and later, the gases moving towards the low pressure areas would move counterclockwise and cause negative magnetic charges.

Table I.

Quarter Year Values Jan. 1, Apr. 1, July 1, Oct. 1. from the Twelve-Month Running Average Sunspot Numbers.

Jan. 1,	1749	—	—	81	88	89	93	83	77	68	57	48	47	47	45	48	45	41	37	31	21
"	1754	17	13	12	14	10	9	10	9	12	11	10	13	17	25	32	39	46	48	48	48
"	1759	46	51	54	59	62	62	63	66	75	81	86	79	71	61	61	58	52	50	45	48
"	1764	49	44	36	29	25	24	21	20	17	12	11	15	20	28	38	43	52	59	70	73
"	1769	78	95	106	116	111	108	101	84	95	86	82	89	77	73	67	59	52	43	35	38
"	1774	39	36	31	18	10	8	7	9	11	13	20	27	44	67	93	118	142	154	154	153
"	1779	139	131	126	115	106	98	85	82	80	74	68	60	49	42	38	36	31	27	23	18
"	1784	13	10	10	9	13	18	24	33	48	64	83	99	110	121	132	139	140	140	131	127
"	1789	126	119	118	115	108	100	90	80	75	70	67	65	63	62	60	59	55	50	47	44
"	1794	41	40	41	37	32	28	21	20	20	19	16	13	10	7	6	6	4	3	4	6
"	1799	8	7	7	6	6	11	15	19	25	29	34	38	41	45	45	45	42	41	43	44
"	1804	45	45	48	49	49	48	42	38	35	31	28	23	20	16	10	8	7	7	8	9
"	1809	7	5	3	1	0	0	0	0	0	1	1	3	3	4	5	5	7	9	12	15
"	1814	15	14	14	17	22	29	35	43	47	47	46	48	43	45	41	32	36	32	30	28
"	1819	24	23	24	23	22	20	16	14	10	7	7	5	6	6	4	3	1	0	2	4
"	1824	6	8	9	9	10	15	17	19	24	27	36	42	47	50	50	53	61	64	63	61
"	1829	60	64	67	71	71	65	71	70	60	59	48	44	41	32	28	19	12	12	9	8
"	1834	8	8	13	15	25	42	57	77	97	106	121	138	141	147	138	128	124	113	103	96
"	1839	81	88	86	81	82	69	63	51	50	43	37	35	27	23	24	21	18	16	11	12
"	1844	11	14	15	21	30	33	40	44	48	58	62	65	66	78	98	114	125	126	124	125
"	1849	119	107	96	85	77	73	67	66	67	65	65	61	59	56	54	48	44	45	39	34
"	1854	29	23	21	19	15	11	7	4	3	4	4	6	10	15	23	32	37	46	55	66
"	1859	77	87	94	94	96	96	96	93	90	84	77	71	68	65	59	59	54	45	44	44
"	1864	44	47	47	43	40	36	31	28	24	19	16	9	6	5	7	11	18	26	37	47
"	1869	60	70	74	89	107	124	139	140	134	123	111	106	99	100	102	102	89	79	66	56
"	1874	52	50	45	36	32	21	17	16	12	12	11	10	13	13	12	10	7	5	3	2
"	1879	2	4	6	12	17	26	32	38	45	49	54	58	62	58	60	57	56	59	64	73
"	1884	74	73	63	55	57	55	52	48	39	31	25	18	13	12	13	13	11	8	7	6
"	1889	5	7	6	6	5	5	7	10	19	28	36	48	58	66	73	75	78	82	85	86
"	1894	87	83	78	76	70	65	64	60	52	48	42	39	34	31	26	27	27	25	27	22
"	1899	20	16	12	11	11	11	9	7	5	4	3	4	3	3	5	7	11	16	24	29
"	1904	35	41	42	51	52	56	64	59	62	64	54	63	59	58	62	50	51	53	49	54
"	1909	50	40	44	36	32	29	19	14	12	9	6	4	3	3	4	4	3	2	1	2
"	1914	4	6	10	18	27	40	47	53	59	54	57	63	71	93	104	103	96	86	81	77
"	1919	80	72	64	62	48	40	38	30	30	30	26	27	21	16	14	7	7	6	6	6
"	1924	9	13	17	20	26	31	44	57	62	65	64	67	72	72	69	69	70	78	78	73
"	1929	67	59	65	62	56	48	36	31	28	25	21	17	15	13	11	12	9	8	6	3
"	1934	5	7	9	13	17	24	36	49	58	67	80	91	104	118	114	111	109	107	110	103
"	1939	103	98	89	86	76	69	68	63	57	53	48	48	46	34	31	24	20	19	16	12
"	1944	9	8	10	13	20	26	33	46	57	75	92	106	131	149	156	148	149	141	136	151
"	1949	137	135	136	123	117	102	83	72	72	71	69	62	49	37	31					

Table 2. Periodic Table Strengths of Sunspot Numbers.

Length of Cycle in Years	Strength	Number of Lines in Table	Length of Cycle in Years	Strength	Number of Lines in Table	Length of Cycle in Years	Strength	Number of Lines in Table	Length of Cycle in Years	Strength	Number of Lines in Table
3.00000	45.46	64	8.27174	56.48	23	9.81579	61.58	19	11.19118	76.18	17
3.06250	46.67	64	8.29348	57.57	23	9.82895	62.58	19	11.20588	75.94	17
3.12500	46.70	60	8.31522	58.13	23	9.84210	62.63	19	11.22059	76.53	17
3.18750	45.58	60	8.33696	59.43	23	9.85526	63.74	19	11.23529	77.24	17
3.25000	46.10	60	8.35870	* 60.17	23	9.86842	63.68	19	11.25000	* 77.88	17
3.37500	45.64	56	8.38043	59.87	23	9.88158	63.42	19	11.26471	76.71	17
3.50000	46.50	54	8.42391	59.22	23	9.89474	63.05	19	11.27941	76.88	17
3.62500	47.52	52	8.45652	57.91	23	9.90790	62.74	19	11.29412	76.47	17
3.75000	46.96	50	8.50000	54.39	23	9.92105	63.63	19	11.30882	75.82	17
3.87500	48.23	48	8.50000	54.82	22	9.93421	* 63.84	19	11.32353	75.82	17
4.00000	47.38	48	8.54545	55.05	22	9.94737	63.16	19	11.33823	75.35	17
4.12500	48.59	46	8.59090	54.82	22	9.96053	63.11	19	11.35294	76.47	17
4.25000	47.23	44	8.63636	56.32	22	9.97368	62.42	19	11.36765	74.82	17
4.37500	47.73	44	8.68182	57.95	22	9.98684	61.74	19	11.38235	75.29	17
4.50000	48.19	42	8.72727	59.05	22	10.00000	62.21	19	11.39706	74.65	17
4.62500	48.97	40	8.75000	59.95	22	10.01316	62.68	19	11.41176	74.94	17
4.75000	47.02	40	8.75000	61.86	21	10.05263	60.37	19	11.42647	74.35	17
4.87500	49.16	38	8.76190	* 62.33	21	10.09211	60.16	19	11.44118	74.47	17
5.00000	47.71	38	8.77381	61.90	21	10.13158	57.32	19	11.45588	74.59	17
5.12500	47.58	36	8.78571	61.57	21	10.17105	55.21	19	11.47059	73.65	17
5.25000	48.03	36	8.82143	60.57	21	10.25000	54.21	19	11.48529	74.57	17
5.37000	49.14	36	8.89286	55.33	21	10.25000	55.50	18	11.50000	73.82	17
5.50000	50.97	34	8.92857	53.14	21	10.29167	54.11	18	11.51471	73.29	17
5.62500	* 51.50	34	8.96429	51.48	21	10.33333	52.50	18	11.52941	74.35	17
5.75000	49.91	34	9.00000	49.48	21	10.37500	52.28	18	11.54412	73.76	17
5.87000	49.94	32	9.03571	48.71	21	10.41667	54.17	18	11.55882	73.29	17
6.00000	48.13	32	9.07143	48.52	21	10.45833	55.33	18	11.57353	72.94	17
6.12500	47.94	32	9.10714	49.76	21	10.50000	58.28	18	11.58824	73.29	17
6.25000	48.40	30	9.17857	55.24	21	10.54167	58.78	18	11.57813	76.94	16
6.37500	47.00	30	9.25000	57.86	21	10.55555	58.83	18	11.59375	76.63	16
6.50000	47.03	30	9.25000	58.35	20	10.56944	59.50	18	11.60938	75.81	16
6.75000	48.50	28	9.27500	58.40	20	10.58333	59.67	18	11.62500	75.94	16
7.00000	48.00	27	9.28750	57.50	20	10.59722	* 59.83	18	11.64063	75.06	16
7.25000	50.96	26	9.30000	* 58.90	20	10.61111	58.94	18	11.65625	73.88	16
7.50000	52.20	25	9.32500	58.45	20	10.62500	57.94	18	11.67188	73.94	16
7.55000	51.88	25	9.35000	57.95	20	10.66667	57.06	18	11.68750	72.44	16
7.58000	53.04	25	9.37500	57.35	20	10.70833	55.44	18	11.70313	72.31	16
7.59000	52.68	25	9.40000	57.20	20	10.75000	54.78	18	11.71875	71.13	16
7.60000	* 53.56	25	9.42500	55.85	20	10.79167	55.28	18	11.73438	71.00	16
7.61000	53.12	25	9.45000	54.15	20	10.83323	57.22	18	11.75000	70.00	16
7.65000	52.04	25	9.47500	52.90	20	10.87500	61.83	18	11.76562	68.75	16
7.70000	51.04	25	9.50000	53.40	20	10.88235	61.23	17	11.78125	67.38	16
7.75000	50.72	25	9.52500	53.75	20	10.92647	64.59	17	11.79687	66.94	16
7.75000	52.25	24	9.55000	52.90	20	10.97059	68.71	17	11.81250	65.38	16
7.79167	49.21	24	9.57500	51.85	20	11.00000	71.12	17	11.82812	64.75	16
7.83333	47.83	24	9.60000	50.80	20	11.01471	72.53	17	11.84375	65.00	16
7.87500	47.50	24	9.62500	50.40	20	11.02941	73.82	17	11.85937	62.13	16
7.91667	47.38	24	9.65000	51.55	20	11.04412	73.29	17	11.87500	61.94	16
7.95833	47.50	24	9.67500	53.65	20	11.05882	72.53	17	11.90625	58.81	16
8.00000	49.21	24	9.70000	56.30	20	11.07353	73.41	17	11.95312	57.06	16
8.04167	50.83	24	9.72500	57.25	20	11.08824	73.88	17	12.00000	55.19	16
8.08333	54.04	24	9.75000	58.60	20	11.10294	74.24	17	12.25000	53.81	16
8.12500	54.46	24	9.75000	59.21	19	11.11765	74.29	17	12.50000	50.13	15
8.11957	55.65	23	9.76316	60.79	19	11.13235	74.24	17	12.75000	49.53	15
8.16304	55.87	23	9.77632	60.37	19	11.14706	75.06	17	13.00000	50.13	15
8.20652	55.83	23	9.78947	60.95	19	11.16177	76.12	17			
8.25000	55.74	23	9.80263	60.84	19	11.17647	75.29	17			

Table 3.

11.25000 Year Periodic Table of the Quarter Year Values from the Twelve Month Average Sunspot Numbers

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1759.00	17	13	12	14	10	9	10	9	12	11	10	13	17	25	32	39	46	48	48	48	46	51	54	59	62	62	63	66	75	81	86	79	71	61	61	58	52	50	45	48	49	44	36	29	25
1765.25	24	21	20	17	12	11	15	20	28	38	43	52	59	70	73	78	95	106	116	111	108	101	84	95	86	82	89	77	73	67	59	52	43	35	38	39	38	31	18	10	8	7	9	11	13
1776.50	20	27	44	67	93	118	142	154	154	153	139	131	126	115	106	98	85	82	80	74	68	60	49	42	38	36	31	27	23	18	13	10	10	9	13	18	24	33	48	64	83	99	110	121	132
1787.75	139	140	140	131	127	126	119	118	115	108	100	90	80	75	70	67	65	63	62	60	59	55	50	47	44	41	40	41	37	32	28	21	20	20	19	16	13	10	7	6	6	4	3	4	6
1799.00	8	7	7	6	6	11	15	19	25	29	34	38	41	45	45	45	42	41	43	44	45	45	48	49	49	48	42	38	35	31	28	23	20	16	10	8	7	7	8	9	7	5	3	1	0
1810.25	0	0	0	0	1	1	3	3	4	5	5	7	9	12	15	15	14	14	17	22	29	35	43	47	47	46	48	43	45	41	32	36	32	30	28	24	23	24	23	22	20	16	14	10	7
1821.50	7	5	6	6	4	3	1	0	2	4	6	8	9	9	10	15	17	19	24	27	36	42	47	50	50	53	61	64	63	61	60	64	67	71	71	65	71	70	60	59	48	44	41	32	28
1832.75	19	12	12	9	8	8	8	13	15	25	42	57	77	97	106	121	138	141	147	138	128	124	113	103	96	81	88	86	81	82	69	63	51	50	43	37	35	27	23	24	21	18	16	11	12
1844.00	11	14	15	21	30	33	40	44	48	58	62	65	66	78	98	114	125	126	124	125	119	107	96	85	77	73	67	66	67	65	65	61	59	56	54	48	44	45	39	34	29	23	21	19	15
1855.25	11	7	4	3	4	4	6	10	15	23	32	37	46	55	66	77	87	94	94	96	96	96	93	90	84	77	71	68	65	59	59	54	45	44	44	44	47	47	43	40	36	31	28	24	19
1866.50	16	9	6	5	7	11	18	26	37	47	60	70	74	89	107	124	139	140	134	123	111	106	99	100	102	102	89	79	66	56	52	50	45	36	32	21	17	16	12	12	11	10	13	13	12
1877.75	10	7	5	3	2	2	4	6	12	17	26	32	38	45	49	54	58	62	58	60	57	56	59	64	73	74	73	63	55	57	55	52	48	39	31	25	18	13	12	13	13	11	8	7	6
1889.00	5	7	6	6	5	5	7	10	19	28	36	48	58	66	73	75	78	82	85	86	87	83	78	76	70	65	64	60	52	48	42	39	34	31	26	27	27	25	27	22	20	16	12	11	11
1900.25	11	9	7	5	4	3	4	3	3	5	7	11	16	24	29	35	41	42	51	52	56	64	59	62	64	54	63	59	58	62	50	51	53	49	54	50	40	44	36	32	29	19	14	12	9
1911.50	6	4	3	3	4	4	3	2	1	2	4	6	10	18	27	40	47	53	59	54	57	63	71	93	104	103	96	86	81	77	80	72	64	62	48	40	38	30	30	30	26	27	21	16	14
1922.75	7	7	6	6	6	9	13	17	20	26	31	44	57	62	65	64	67	72	72	69	69	70	78	78	73	67	59	65	62	56	48	36	31	28	25	21	17	15	13	11	12	9	8	6	3
1934.00	5	7	9	13	17	24	36	49	58	67	80	91	104	118	114	111	109	107	110	103	103	98	89	86	76	69	68	63	57	53	48	48	46	34	31	24	20	19	16	12	9	8	10	13	20
Average 17 Cycles	18.59	17.41	17.76	18.53	20.00	22.47	26.12	29.59	33.41	38.00	42.18	47.06	52.18	59.00	63.82	68.94	73.71	76.00	$\boxed{77.88}$	76.00	74.94	73.88	71.18	72.12	70.29	66.65	65.41	61.82	58.53	55.65	51.41	47.71	43.47	39.47	36.94	33.24	31.12	29.76	27.06	26.35	25.12	23.00	21.59	20.00	19.53

Table 4

9.93421 Year Periodic Table of the Quarter Year Values from the Twelve Month Average Sunspot Numbers

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1756.00	12	11	10	13	17	25	32	39	46	48	48	48	46	51	54	59	62	62	63	66	75	81	86	79	71	61	61	58	52	50	45	48	49	44	36	29	25	24	21	20
1766.00	17	12	11	15	20	28	38	43	52	59	70	73	78	95	106	116	111	108	101	84	95	86	82	89	77	73	67	59	52	43	35	38	39	36	31	18	10	8	7	—
1775.75	9	11	13	20	27	44	67	93	118	142	154	154	153	139	131	126	115	106	98	85	82	80	74	68	60	49	42	38	36	31	27	23	18	13	10	10	9	13	18	24
1785.75	33	48	64	83	99	110	121	132	139	140	140	134	127	126	119	118	115	108	100	90	80	75	70	67	65	63	62	60	59	55	50	47	44	41	40	41	37	32	28	21
1795.75	20	20	19	16	13	10	7	6	6	4	3	4	6	8	7	7	6	6	11	15	19	25	29	34	38	41	45	45	45	42	41	43	44	45	45	48	49	49	48	42
1805.75	38	35	31	28	23	20	16	10	8	7	7	8	9	7	5	3	1	0	0	0	0	0	1	1	3	3	4	5	5	7	9	12	15	15	14	14	17	22	29	—
1815.50	35	43	47	47	46	48	43	45	41	32	36	32	30	28	24	23	24	23	22	20	16	14	10	7	7	5	6	6	4	3	1	0	2	4	6	8	9	9	10	15
1825.50	17	19	24	27	36	42	47	50	50	53	61	64	63	61	60	64	67	71	71	65	71	70	60	59	48	44	41	32	28	19	12	12	9	8	8	8	13	15	25	42
1835.50	57	77	97	106	121	138	141	147	138	128	124	113	103	96	81	88	86	81	82	69	63	51	50	43	37	35	27	23	24	21	18	16	11	12	11	14	15	21	30	33
1845.50	40	44	48	58	62	65	66	78	98	114	125	126	124	125	119	107	96	85	77	73	67	66	67	65	65	61	59	56	54	48	44	45	39	34	29	23	21	19	15	—
1855.25	11	7	4	3	4	4	6	10	15	23	32	37	46	55	66	77	87	94	94	96	96	96	93	90	84	77	71	68	65	59	59	54	45	44	44	44	47	47	43	40
1865.25	36	31	28	24	19	16	9	6	5	7	11	18	26	37	47	60	70	74	89	107	124	139	140	134	123	111	106	99	100	102	102	89	79	66	56	52	50	45	36	32
1875.25	21	17	16	12	12	11	10	13	13	12	10	7	5	3	2	2	4	6	12	17	26	32	38	45	49	54	58	62	58	60	57	56	59	64	73	74	73	63	55	57
1885.25	55	52	48	39	31	25	18	13	12	13	13	11	8	7	6	5	7	6	6	5	5	7	10	19	28	36	48	58	66	73	75	78	82	85	86	87	83	78	76	—
1895.00	70	65	64	60	52	48	42	39	34	31	26	27	27	25	27	22	20	16	12	11	11	11	9	7	5	4	3	4	3	3	5	7	11	16	24	29	35	41	42	57
1905.00	52	56	64	59	62	64	54	63	59	58	62	50	51	53	49	54	50	40	44	36	32	29	19	14	12	9	6	4	3	3	4	4	3	2	1	2	4	6	10	18
1915.00	27	40	47	53	59	54	57	63	71	93	104	103	96	86	81	77	80	72	64	62	48	40	38	30	30	30	26	27	21	16	14	7	7	6	6	6	9	13	17	20
1925.00	26	31	44	57	62	65	64	67	72	72	69	69	70	78	78	73	67	59	65	62	56	48	36	31	28	25	21	17	15	13	11	12	9	8	6	3	5	7	9	—
1934.75	13	17	24	36	49	58	67	80	91	104	118	114	111	109	107	110	103	103	98	89	86	76	69	68	63	57	53	48	48	46	34	31	24	20	19	16	12	9	8	10
Average 19 Cycles	31.00	33.47	37.00	39.79	42.84	46.05	47.63	52.47	56.21	60.00	$\boxed{63.84}$	62.58	62.05	62.58	61.53	62.08	61.63	58.95	58.37	55.37	55.37	54.00	51.63	50.00	47.00	44.10	42.42	40.47	38.84	36.53	33.84	32.74	31.00	29.63	28.68	27.68	27.53	27.42	27.74	(29.37)

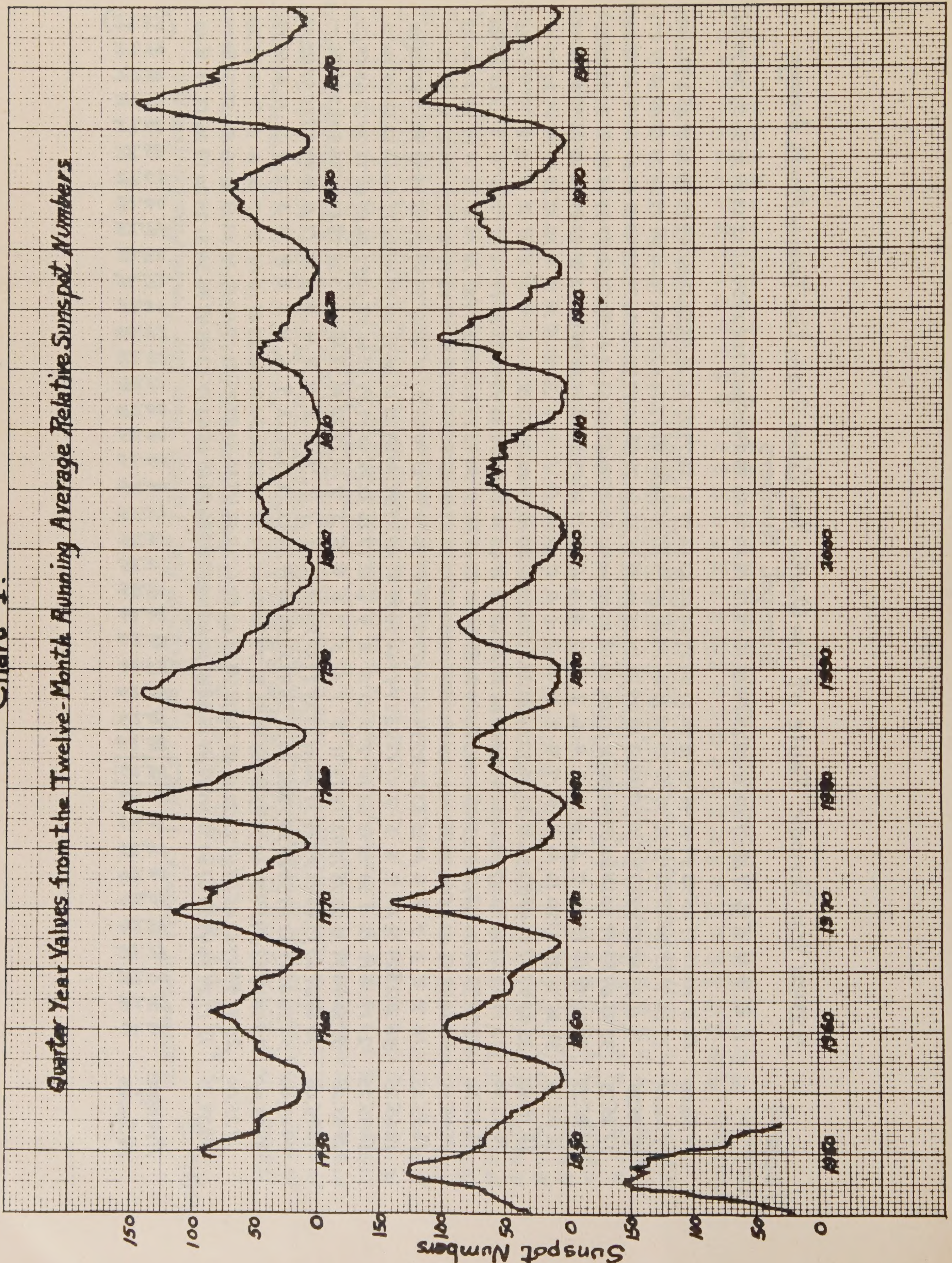


Chart I.

Quarter Year Values from the Twelve-Month Running Average Relative Sunspot Numbers

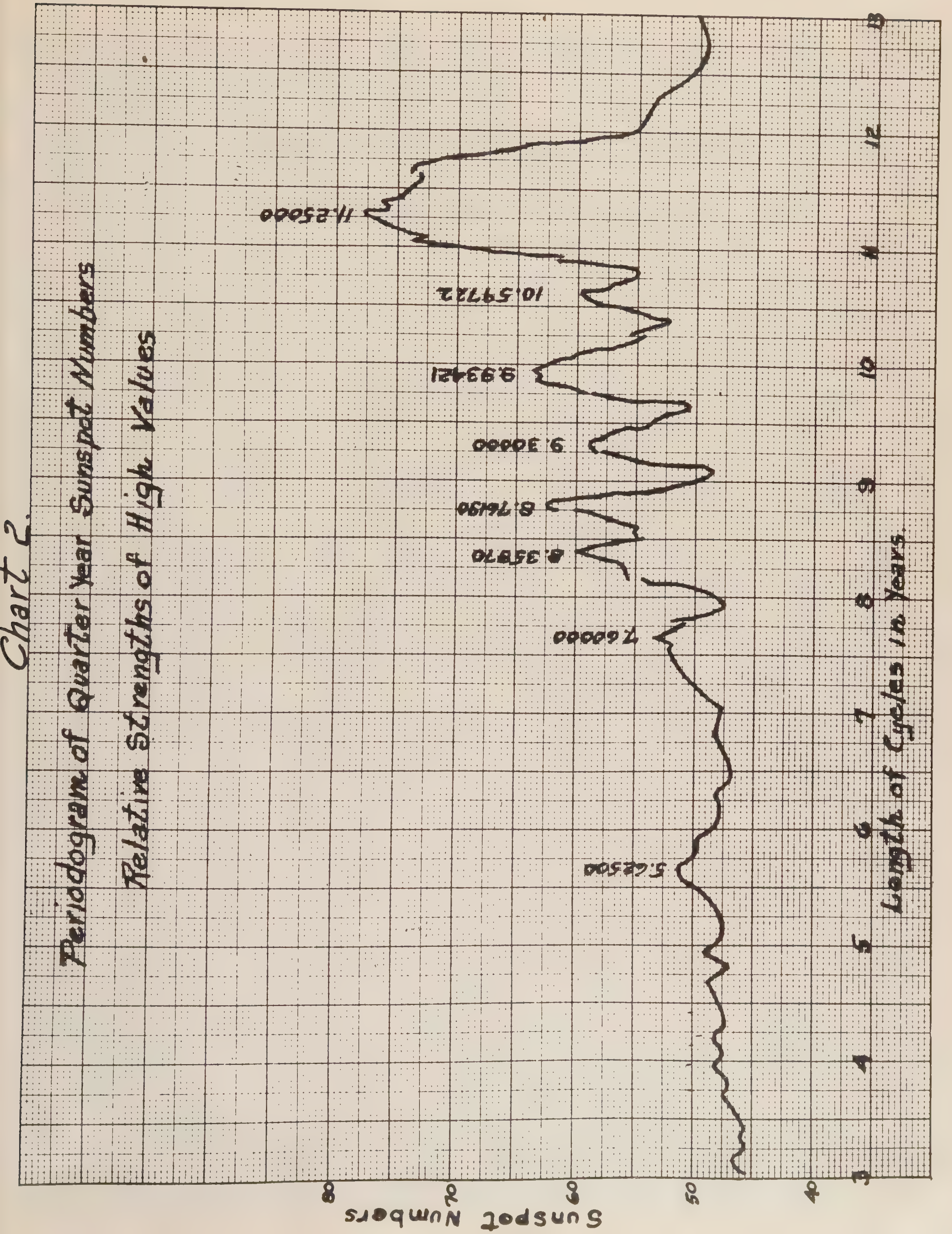


Chart 2.
Periodogram of Quarter Year Sunspot Numbers
Relative Strengths of High Values
11.25000
10.59722
9.93421
9.30000
8.76190
8.35870
7.60000
5.62500
3
4
5
6
7
8
9
10
11
12
13
Length of Cycles in Years
80
70
60
50
40
Sunspot Numbers

Chart 3.

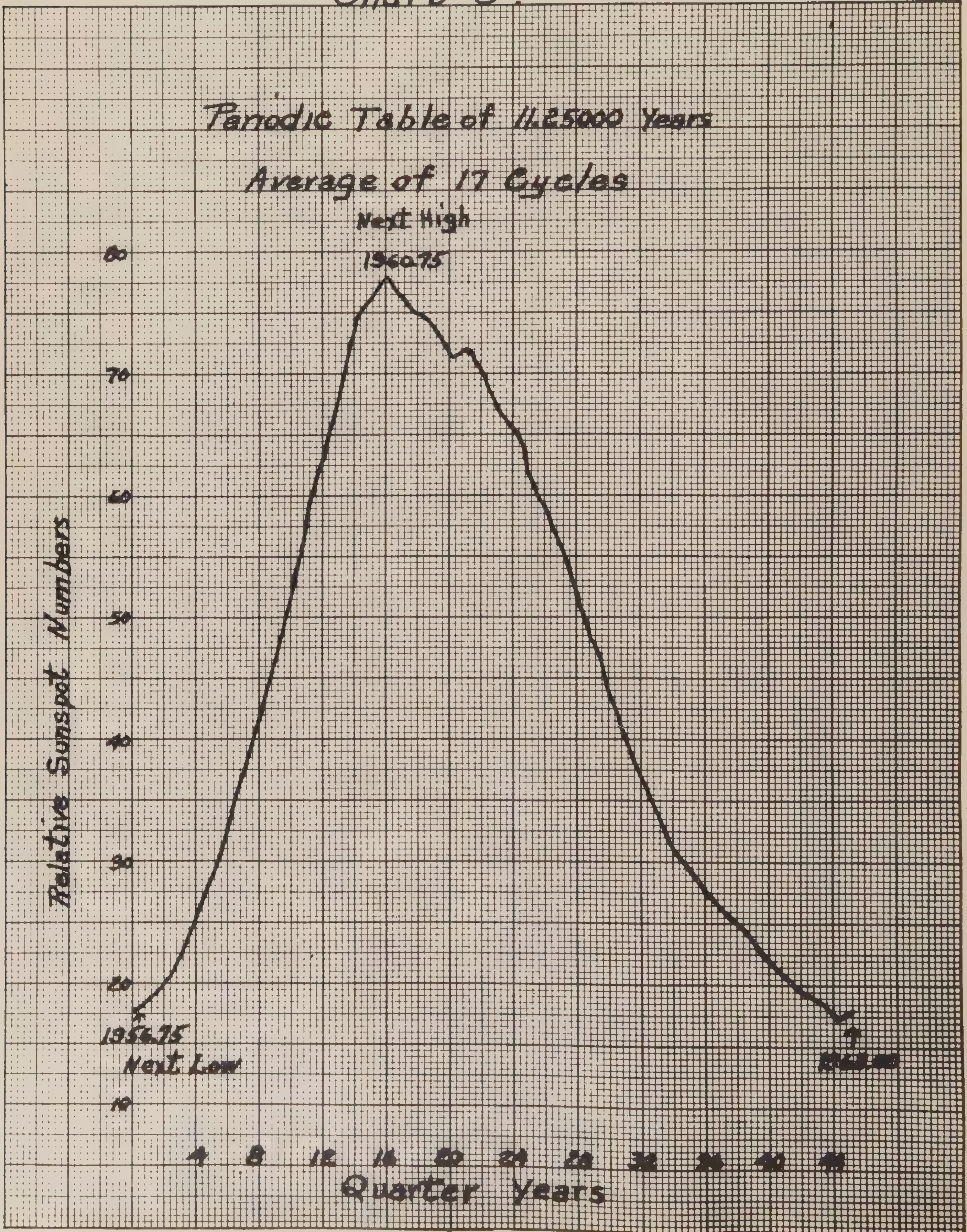

Periodic Table of 11.25000 Years
Average of 17 Cycles
Next High
1960.75
1956.75
Next Low
Relative Sunspot Numbers
80
70
60
50
40
30
20
10
4
8
12
16
20
24
28
32
36
40
44
Quarter Years

Chart 4.

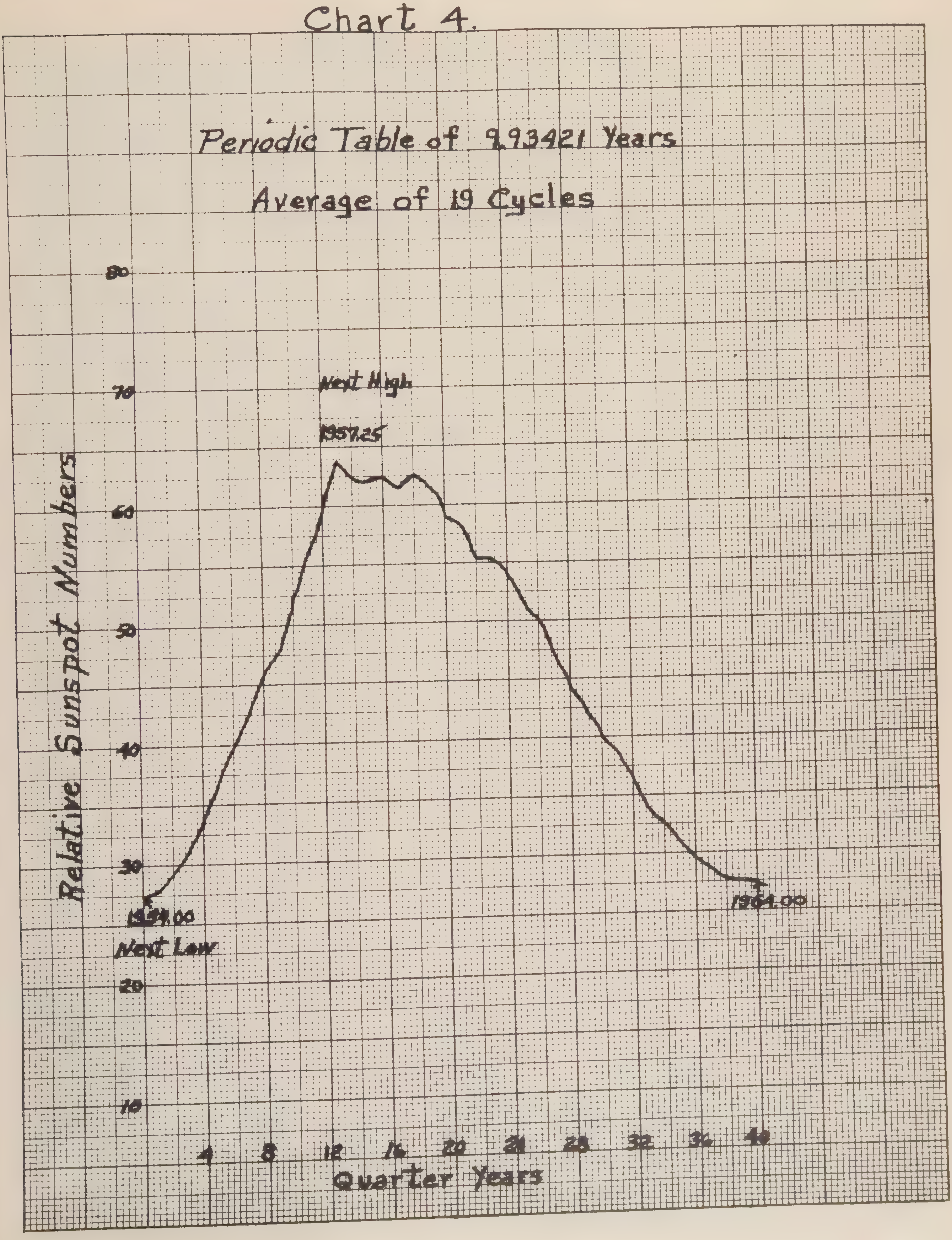

Periodic Table of 9.93421 Years
Average of 19 Cycles
Relative Sunspot Numbers
80
70
60
50
40
30
20
10
Next High
1957.25
1954.00
Next Low
1964.00
4
8
12
16
20
24
28
32
36
40
Quarter Years

Chart 5

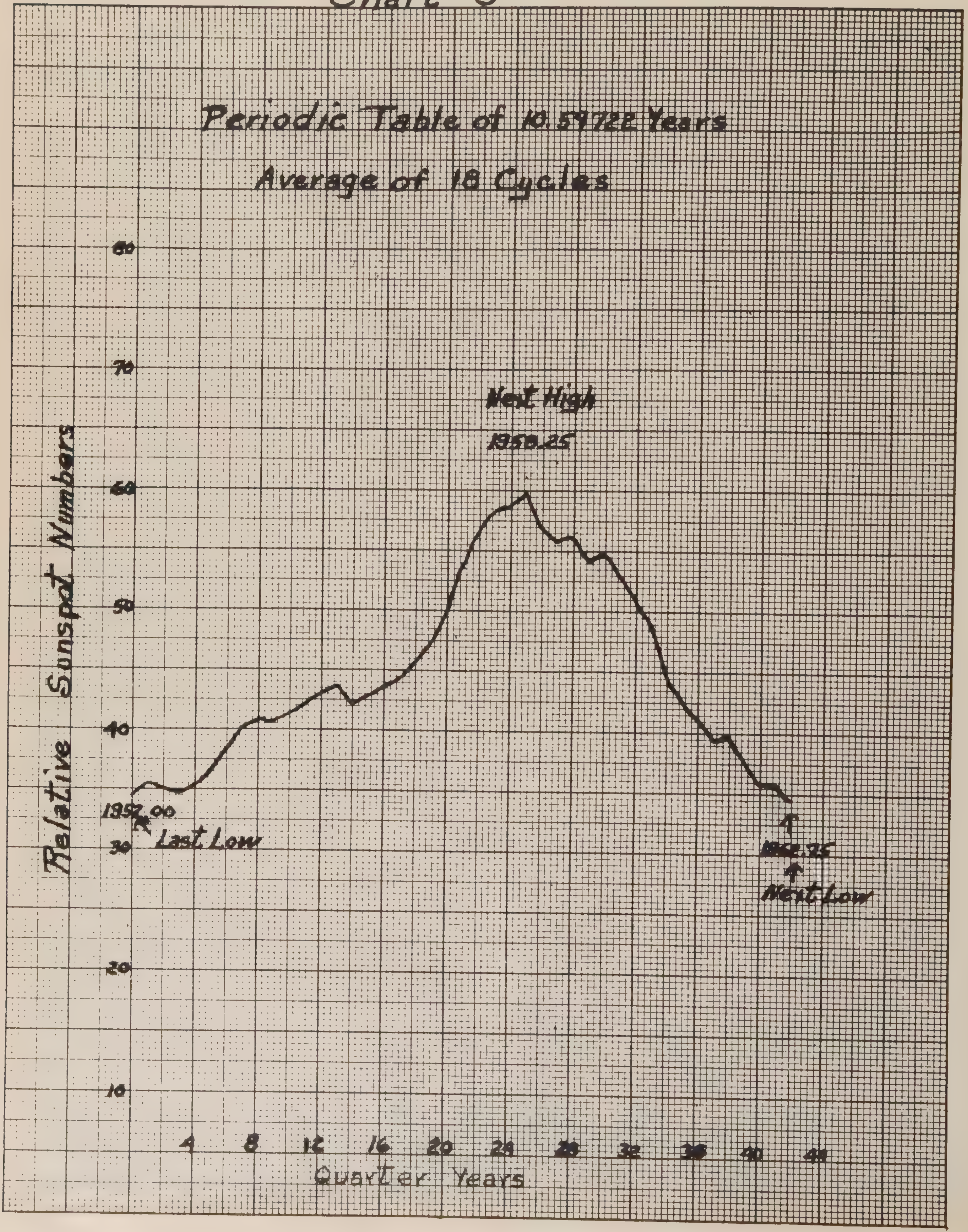
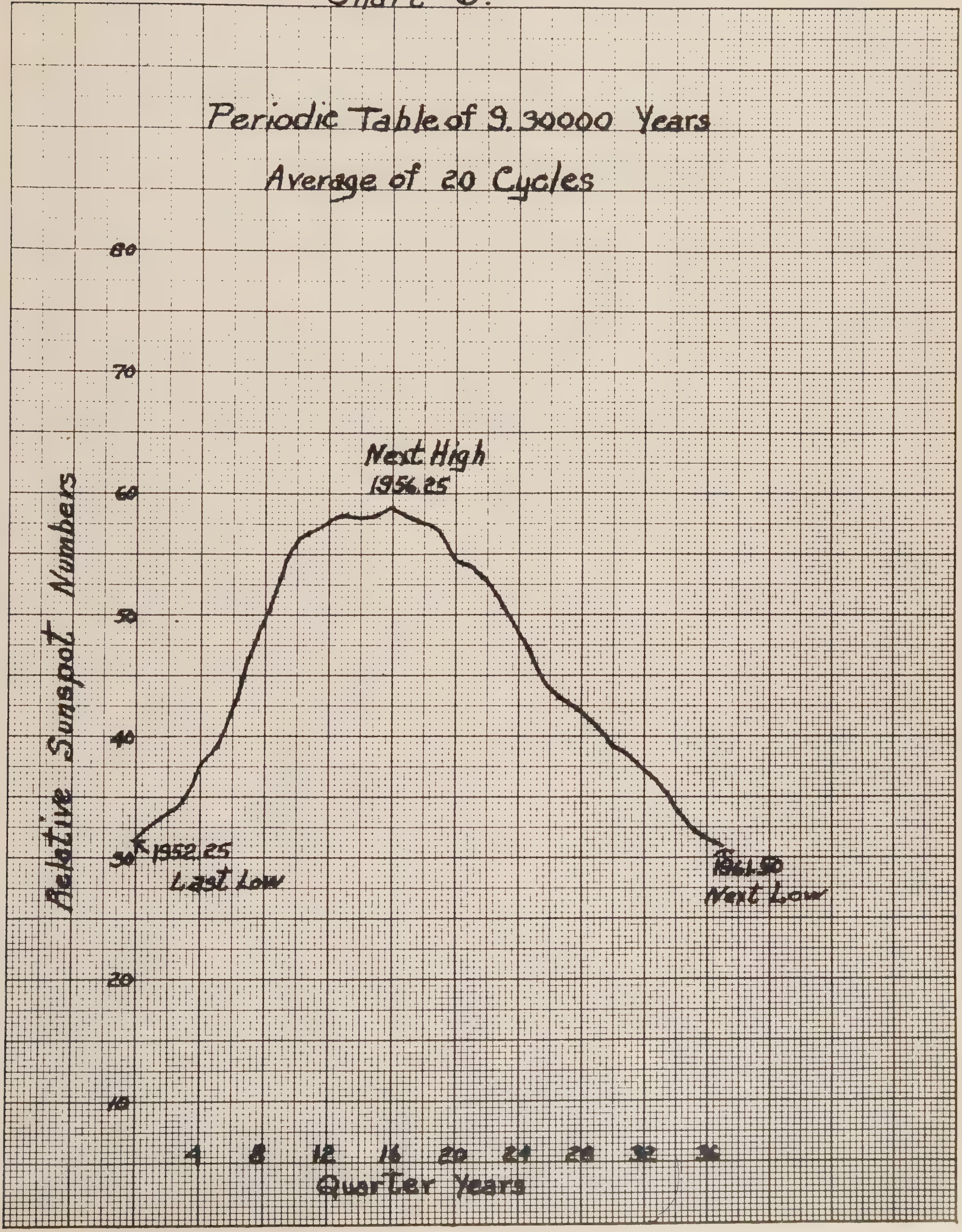

Periodic Table of 10.59722 Years
Average of 18 Cycles
Relative Sunspot Numbers
80
70
60
50
40
30
20
10
Next High
1958.25
1952.00
Last Low
1962.75
Next Low
4
8
12
16
20
24
28
32
36
40
44
Quarter Years

Chart 6.



Periodic Table of 9.30000 Years

Average of 20 Cycles

Chart 7.

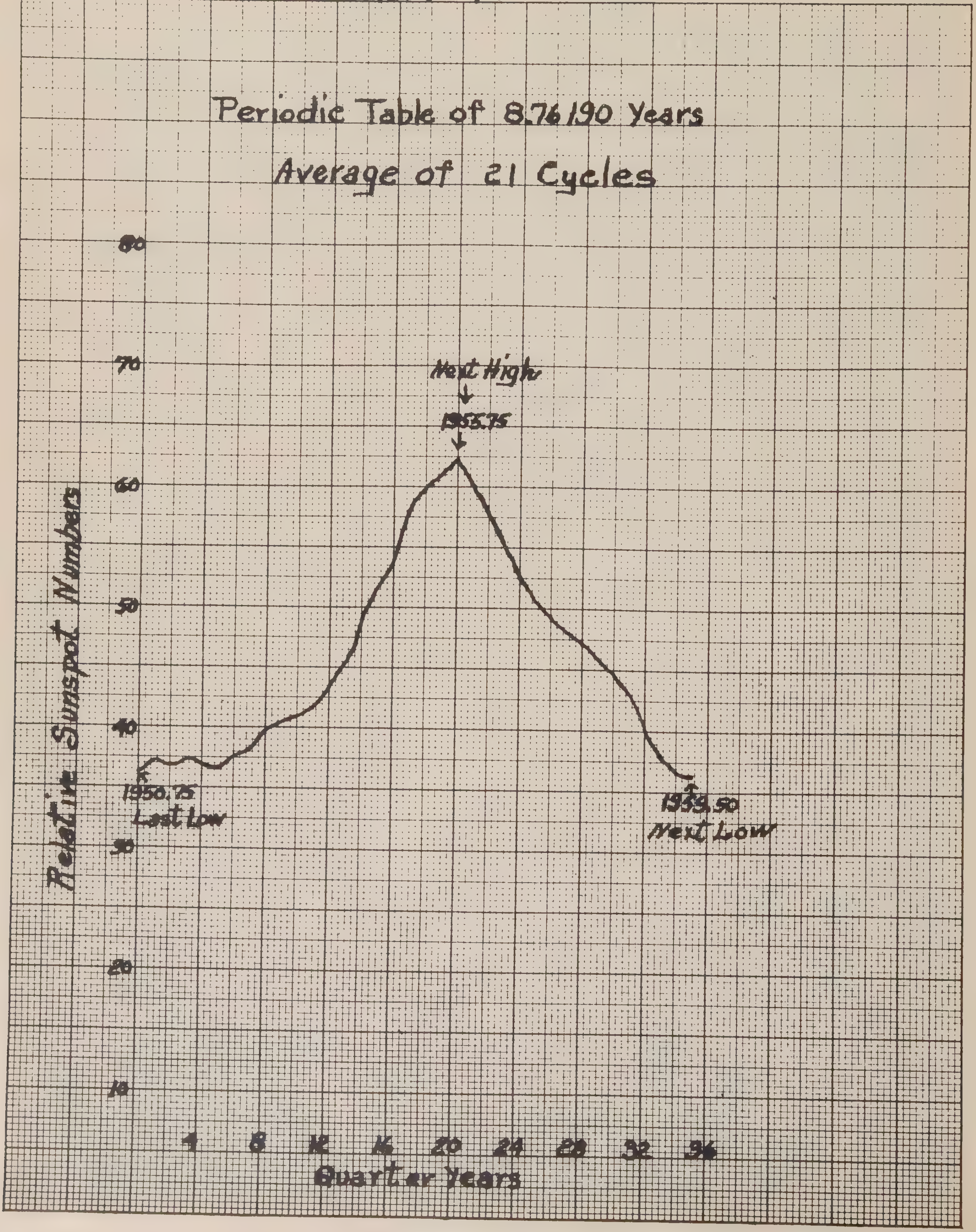

Periodic Table of 8.76190 Years
Average of 21 Cycles
80
70
60
50
40
30
20
10
Relative Sunspot Numbers
Next High
1955.75
1950.75
Last Low
1959.50
Next Low
4
8
12
16
20
24
28
32
36
Quarter Years

Chart 8.

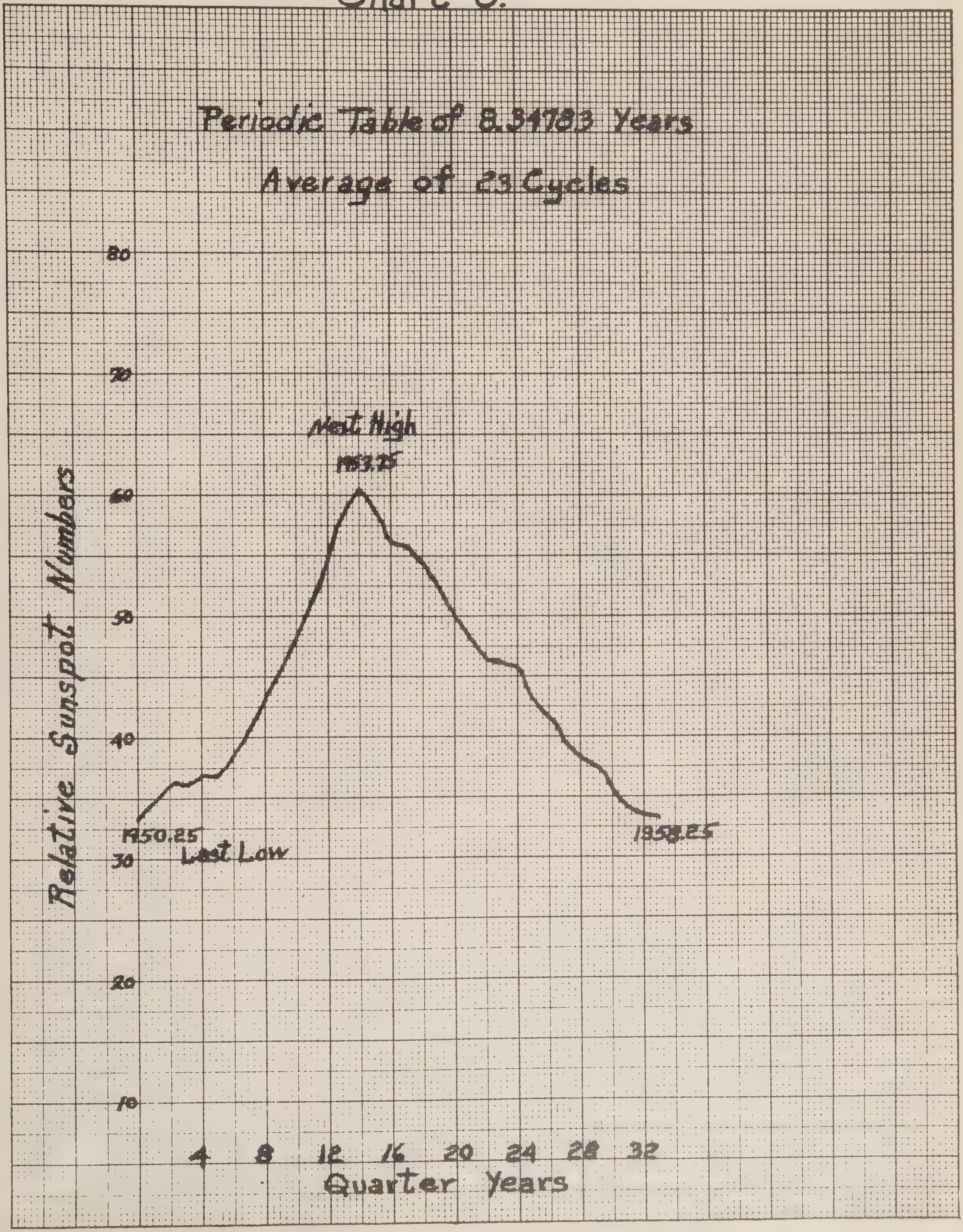
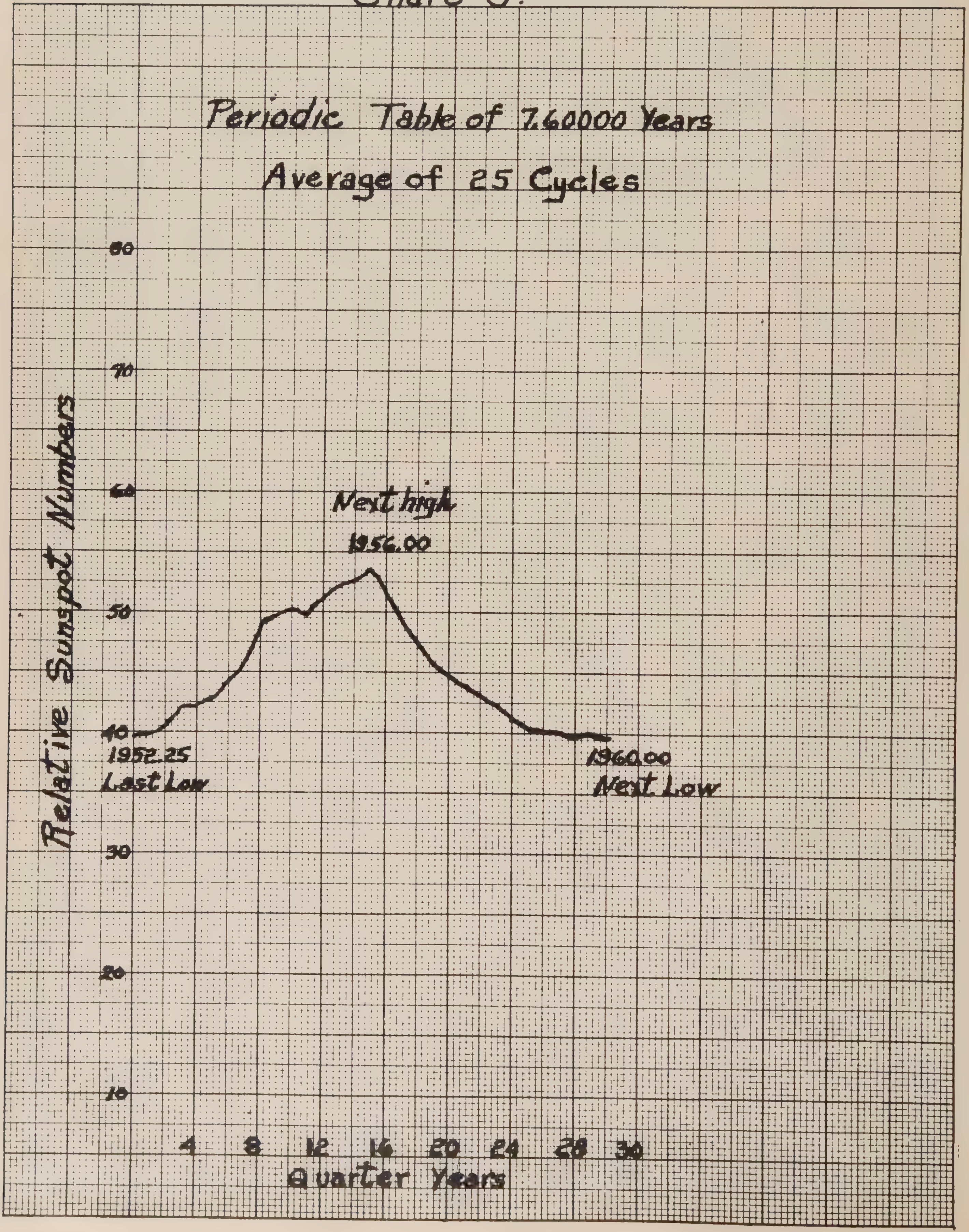

Periodic Table of 8.34783 Years
Average of 23 Cycles
Next High
1953.75
1950.25
Last Low
1958.25
Relative Sunspot Numbers
80
70
60
50
40
30
20
10
4
8
12
16
20
24
28
32
Quarter Years

Chart 9.


Periodic Table of 7.60000 Years
Average of 25 Cycles
Relative Sunspot Numbers
80
70
60
50
40
30
20
10
Next high
1956.00
1952.25
Last Low
1960.00
Next Low
4
8
12
16
20
24
28
30
Quarter Years

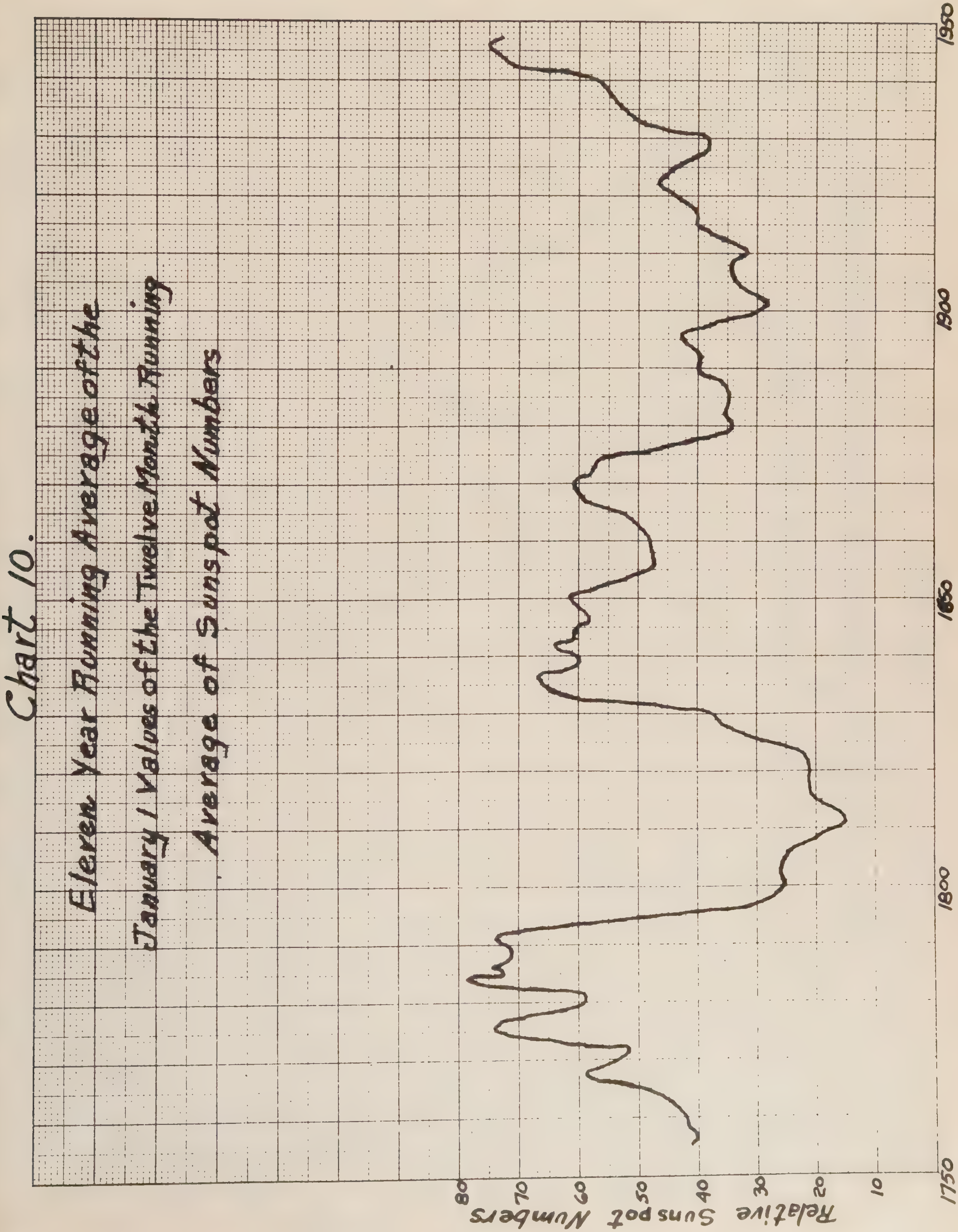


Chart 10.

Eleven Year Running Average of the January 1 Values of the Twelve Month Running Average of Sunspot Numbers

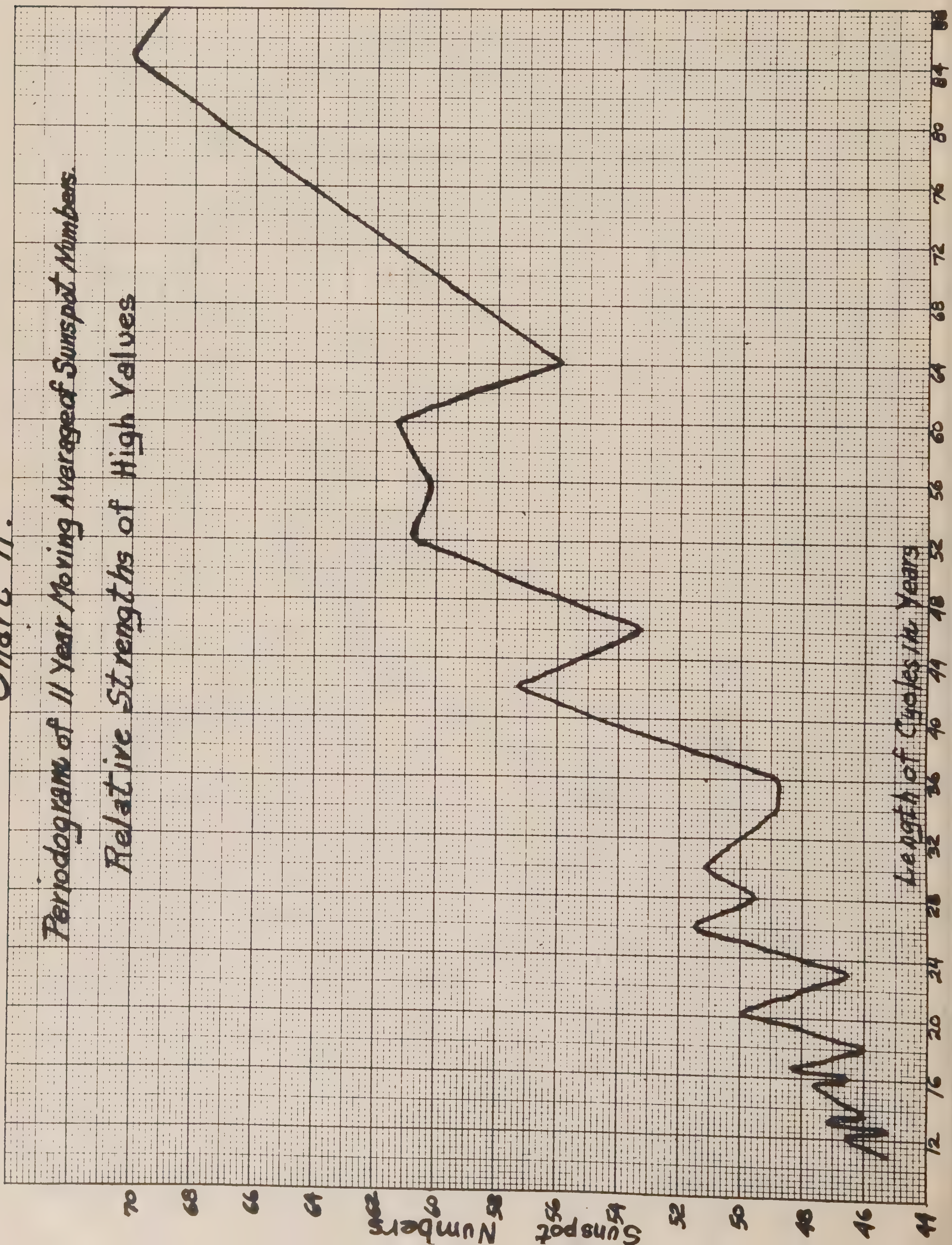


Chart 11.

Periodogram of 11 Year Moving Averages of Sunspot Numbers.

Relative Strengths of High Values

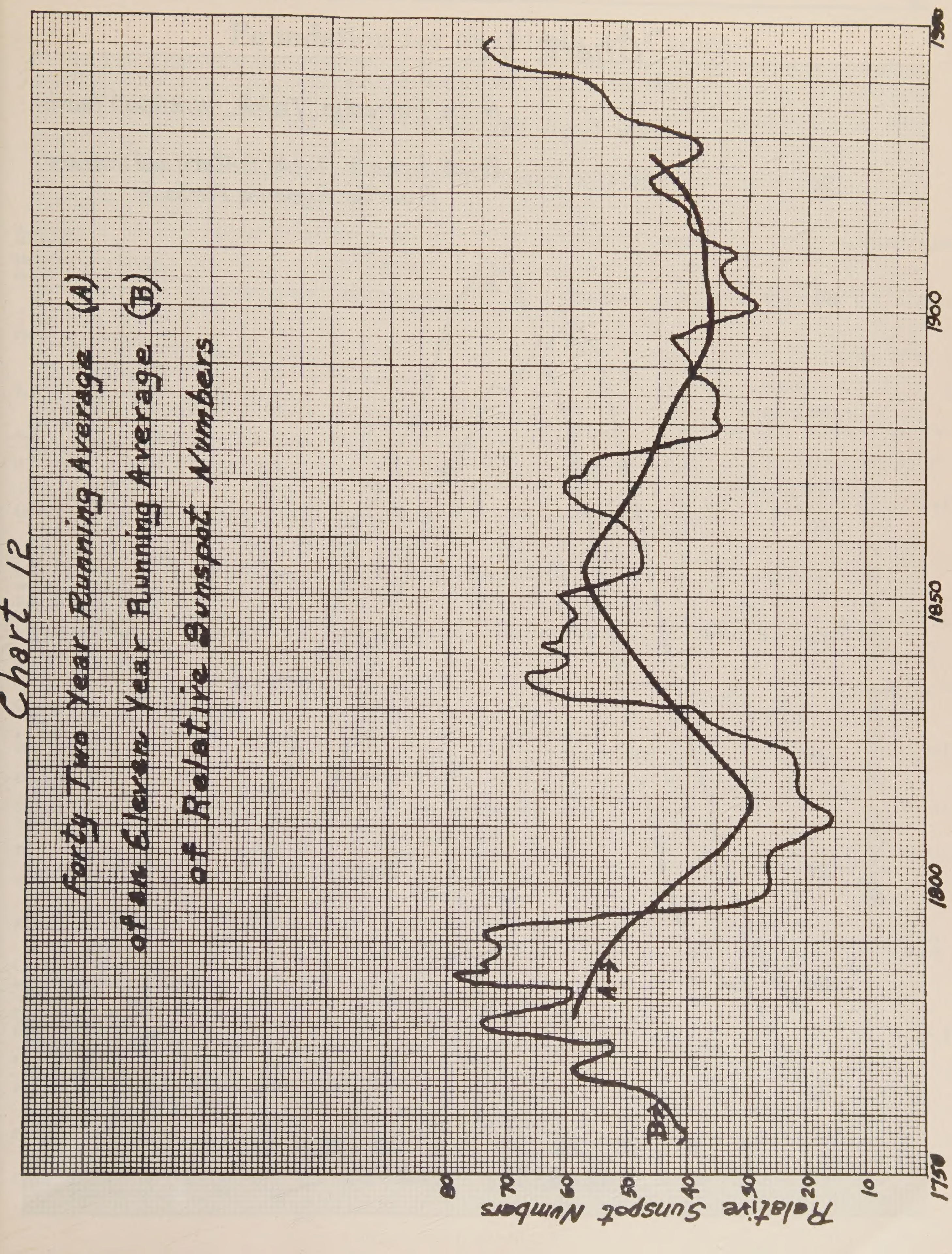
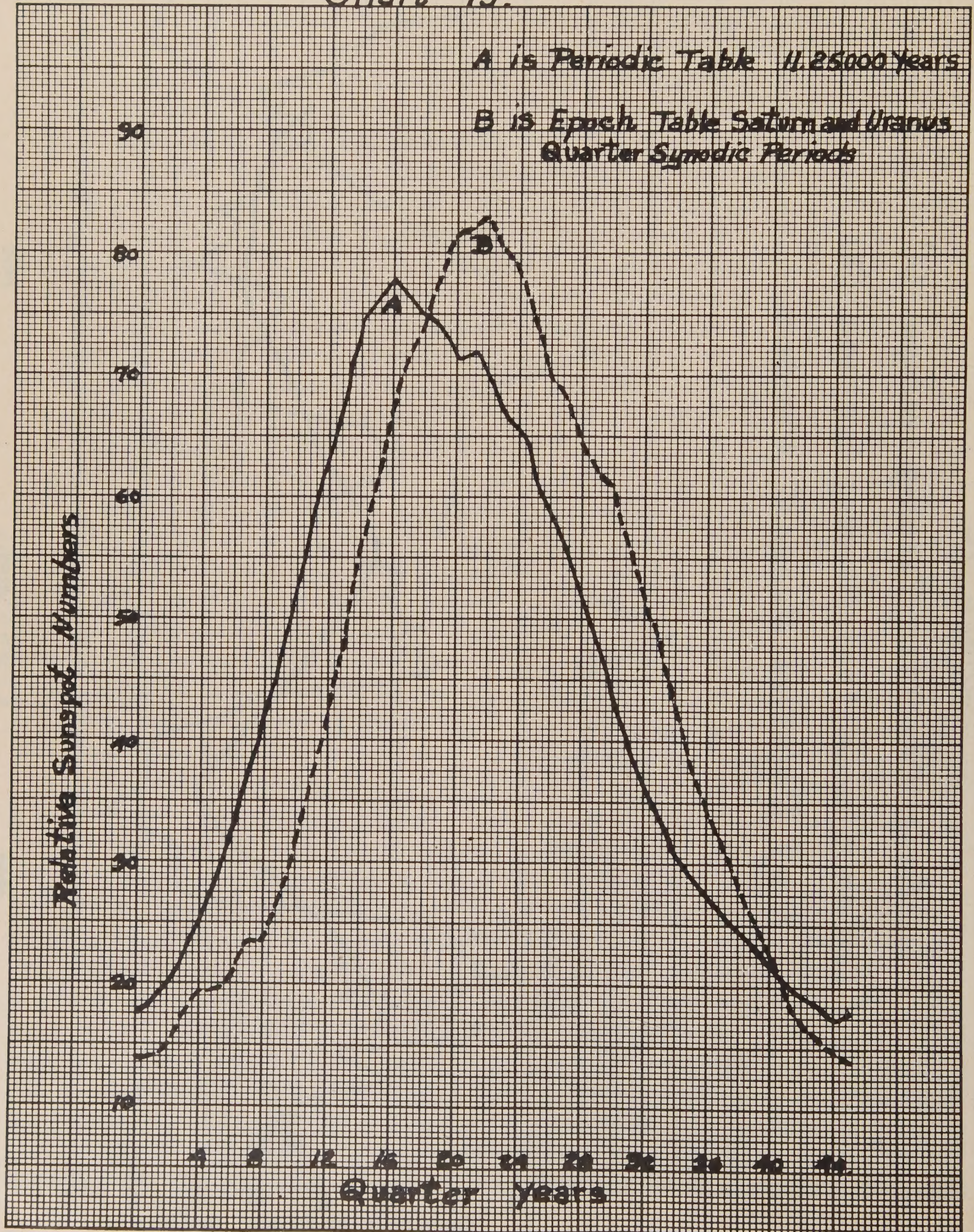


Chart 12

Forty Two Year Running Average (A)
of an Eleven Year Running Average (B)
of Relative Sunspot Numbers

Chart 13.


A is Periodic Table 11.25000 Years
B is Epoch Table Saturn and Uranus Quarter Synodic Periods
A
B
Relative Sunspot Numbers
10
20
30
40
50
60
70
80
90
Quarter Years
4
8
12
16
20
24
28
32
36
40
44

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  Cotton Prices
  Rayon Production
  Cotton Production, and
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  Betlehem Steel Company
  E.I. Du Pont De Nemours & Company
  Inland Steel Company
  Jones & Laughlin Steel Corporation
  Monsanto Chemical Company
  Montgomery Ward & Company
  Pittsburgh Plate Glass Company
  Allis-Chalmers Manufacturing Company
  Armour and Company
  General Electric Company
  Republic Steel Corporation
  Sears, Roebuck and Company
  Youngstown Sheet and Tube Company
  Wilson & Company
  Continental Oil Company
  National Lead Company
  Swift & Company
  Armco Steel Corporation
  B. F. Goodrich Company
  Goodyear Tire & Rubber Company
  Seaboard Air Line
  Standard Oil Company of California
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